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DECISION SUPPORT SYSTEMS
AND
THE MARGINAL ECONOMICS OF EFFORT

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Introduction

Decision Support Systems (DSS) are interactive computer models or information aids designed to assist (rather than replace) managerial judgment in unstructured tasks.[1] The assumption underlying Decision Support is that manager-with-machine will be more effective than either alone. There are now many DSS in use in organizations and we can expect an increase in their applications, given the availability of low-cost time-sharing services, networks and minicomputers, and software packages and languages that facilitate speedy development of flexible conversational systems. Recent innovations in microcomputers reinforce that trend and imply an eventual extension of DSS to "personal" computing.[2]

Among proponents of DSS, it is an article of faith that interactive aids to problem-solving improve the effectiveness and managerial decision making. They point to examples of DSS that have led their users to explore more alternative solutions, examine data in more depth and detail and become more analytic in their approach to problems. Such intuitive concepts of improvement in decision processes have provided adequate justification and guidelines for building DSS. They are obviously, however, imprecise in their definitions. It is not at all clear, for instance, how and why examining more alternatives "improves" the "effectiveness" of decision making. A tool that encourages an incompetent individual to expand the range of solutions he or she inadequately assesses seems unlikely to improve anything.

This paper presents some propositions about the impact of a DSS on individual problem-solving that provide both a theoretical framework and some practicle criteria for systems design. It focuses on the marginal economics of effort, the manager's subjective assessment of the relative cognitive effort -- the perceived costs -- of adopting the DSS in relation to the likely improvement in the quality of the decision made. Any DSS is used at the manager's discretion -- if it is used at all. (Of course, there may be institutional pressures to use the system, but in general, the manager can substitute his or her own judgment for the DSS and simply go through the motions of using it.) A decision maker must decide whether to adopt the system, and hence pay the cognitive costs to gain the benefits, or to rely on existing methods of problem-solving. Analytic specialists, such as systems designers and management scientists, tend to assume that their costs are low in relation to the benefits. DSS designers similarly often feel that managers will use a DSS if it clearly provides better solutions or permits more systematic of "rational" evaluation.

However, the argument of this paper is that the marginal economics of effort are such that a DSS or any similar aid may impose costs that outweigh the perceived gains because existing incremental or heuristic strategies are extremely cheap. Managers have an investment in methodologies that have been reasonably effective, so that it may be difficult for any system to generate substantial enough improvements in decision outcomes to justify the cognitive strain imposed. A DSS will be accepted mainly because it provides adequate benefits for low incremental effort.

Many researchers have commented on the impact of "bounded rationality" on the use of analytic aids.[3] Bounded rationality is essentially a constraint on an individual's ability to exploit the potential benefits of some decision aid. While the arguments in this paper fully accept that bounded rationality explains much of the gap between the normative logic of analytic decision making and the descriptive reality of managerial problem-solving, they do not focus on ability as much as willingness to develop or use an ability. A key conclusion is that even if individuals can surmount bounded rationality, they will often choose to continue using simple, low-cost strategies even though they recognize the benefits from shifting towards the rational ideal. Their "purchase" of a decision aid is based on three implicit questions:

1) What increased effort is required (additional computation, learning, conscious articulation, assimilation of results)?

2) What is the likely benefit (better quality of decision, improved reliability, more detailed analysis)?

3) Is it worth it?

Levels of Reaction in Decision Making

Gore (1965) provides a useful starting point for discussing the marginal economics of effort. He argues that the very first step in the decision process is to choose a level of reaction. This determines the cognitive resources to be committed to the problem. If the situation is seen as a routine one, the decision maker uses standard operating procedures. These obviously require minimal effort. If the problem warrants an innovative, adaptive response, he or she will use incremental analysis or heuristics of varying complexity. (Heuristics are rules of thumb that give answers that are "good enough most of the time".) Most obviously, the manager satisfices[4] -- gets an acceptable solution without wasting effort. Only if the situation involves a fundamental problem (Gore uses the term "crisis"), will he or she go through the complex process of formalizing objectives, searching methodically for solutions and systematically evaluating them.

Fairly obviously, the choice of a level of reaction -- which may well turn out to be an incorrect one in retrospect -- reflects an assessment that an increase in effort will not be rewarded by a correspondingly valuable improvement in the decision outcome. Ansoff (1968, introduction), points out that as long as the status quo is acceptable, the marginal economics of effort favor adaptive levels of reaction but that when this is no longer true and a better decision is essential, the costs of analysis are seen as justifiable and organizations move towards the rational ideal.

Bruner summarizes the purpose of problem-solving strategies as being to ease "cognitive strain". Descriptive studies of decision making stress the simplicity of most such strategies. Lindblom's well-known advocacy of incrementalism is based on his belief that it simplifies an almost impossibly complex process of articulating preferences and comparing incommensurate attributes. Incremental decision making limits analysis to a few alternatives close to the status quo and avoids fundamental examination of all "relevant" alternatives. Cyert and March suggest that setting realistic levels of aspiration and relying on directed and limited search balances costs and payoffs. Simon's work on heuristics, satisficing and attention mechanisms in information-processing similarly identifies strategies individuals develop to simplify decision making without making it simplistic. (Taylor, however, suggests that too often we try to loosen the bounds on rationality by evading them -- oversimplifying and distorting the problem.)

Virtually every descriptive paradigm of decision making emphasizes getting good enough solutions at low enough costs. However, the focus on bounded rationality has lead many commentators to assume that the difficulty is one of ability only: "no one in his mind will satisfice if he can just as well optimize" (Simon).[5] The phrase, "just as well" is ambiguous and the assertion seems true only if the ability to optimize -- to loosen the bounds on rationality -- does not impose high marginal costs of effort. The arguments between those who believe in pluralism as ethically and philosophically more valid for handling qualitative tradeoffs among conflicting objectives (Hoos, Lindblom) and the disdainers of simplicity (Ackoff and Sasieni: "(satisficing) appeals to planners who will not stick their necks out")[6] partly reflect differing assessments of the weighting factors individuals place on effort. At one extreme, rationalist theorists treat cognitive costs as non-existent. At the other, they are seen as so heavy as to constrain decision makers to incremental analysis.

To some extent, the weights reflect different cognitive styles and personality traits (see next section). Identifying them will be a venture as complex (and probably futile) as similar attempts to articulate individuals' utility functions. However, the substantial empirical literature in cognitive psychology, organizational decision making, political science and implementation of OR/MS models strongly suggests that for most people, the weighting factor is heavy in relation to that placed on improved decision outcomes. The rest of this paper is based on the assumption that cognitive effort is perceived as simply very expensive and hence to be avoided. Once again, it should be stressed that while bounded rationality implies that effort is difficult and at times impossible, the argument here is that this effort is costly even when feasible.

Categories of Effort

The following summary of categories of effort (see Table 1) has been synthesized from a review of empirical, and hence descriptive, studies of decision making. The classifications were defined in terms that could provide useful insights into design criteria for DSS. They are not intended as a formal theory, although most paradigms of the decision process use similar distinctions or stages (see, for example, Simon's taxonomy of Intelligence-Design-Choice and Gore's summary which includes level of reaction, orientation and implementation/explanation of the solution).

TABLE 1 - CATEGORIES OF COGNITIVE EFFORT

1.	Computation	arithmetic calculation emumeration
2.	Specification	conscious articulation of weights, priorities, preferences point estimates of probabilities or utility functions
3.	Search	scanning creating alternatives
4.	Inference	deriving conclusions from data statistical reasoning generalizing from specific instances
5.	Assimulation	responding to numerical, graphical or verbal information assessing results of analysis "making sense" of data
6.	Explanation	justifying solutions explaining conclusions and/or methodology that leads to them

The most obvious category of effort is Computation. Mental calculation is clearly constrained by intelligence, speed and accuracy. A limited type of DSS, the portable calculator, has been enthusiastically accepted by even those who mistrust computers because it so obviously improves computation and reduces effort.

Specification involves conscious articulation of concepts, preferences, problem criteria and probabilities. Most analytic methodologies require substantial specification and incremental techniques explicitly avoid them. For example, as Lindblom points out, "disjointed marginal incrementalism" allows the analyst to ask only "Do I prefer three oranges to the two apples I have now?" and not to have to specify some preference function for apples and oranges.[7] The literature on assessment of probabilities and preferences (Edwards, Beach) suggests that individuals are inconsistent in Specification and do not find it easy or desirable.

Inference involves drawing conclusions from data. As Tversky and Kahnemann and others have shown, most people are poor statisticians, who make predictable errors, rely on oversimple rules of deduction and fail to make adequate use of the information they have, especially in updating probabilities.[8] Search is not so constrained by ability. It has many indirect costs, especially of computation and inference. The high marginal cost of generating and evaluating an additional alternative explains much of the reliance of most managers on heuristics.

Assimilation of information involves a level of effort that leads many managers to rely on simple verbal presentations rather than to read technical reports in detail. Mintzberg's study of executives, together with the more anecdotal conclusions of analysts and consultants, highlights the unwillingness of managers to commit time and effort to coming to grips with complex information.[9] Wilensky suggests that under stress, groups of decision makers try to reduce the data they must handle; they simplify the problem to the point where it becomes manageable. This reluctance to assimilate information may be explained in terms of laziness, but not in terms of ability. Mintzberg's and Stewart's similar studies do not imply a lack of intelligence among senior managers, who generally are energetic, even driven. If we assume a high weighting factor placed on the effort required in assimilation, this apparent weakness or fault becomes more understandable.

The final category of effort is not generally addressed in the literature on organizational decision making that focuses on cognitive processes, though Gore highlights it as a separate phase of the decision process. Explanation involves either translating a choice of solution into action or justifying it to others. In both cases, the analysis, whether intuitive or analytic, must be communicated to individuals who may not have shared in the process. Fairly often, the organization has well-established procedures and formats for this. Cost-benefit analysis or capital budgeting methods, for example, provide a specific structure for explanation. If the managers' own decisions are based on intuition or heuristics, they may find the translation to the institutionalized formats close to impossible.

Individual Differences

The above categories of effort all involve a mix of ability and inclination. For some individuals, certain costs are seen as low. Analytic thinkers, for example, naturally structure problems, rely on conscious methodologies and clarify criteria. They thus do not avoid specification (Keen, McKenney and Keen). Others are cognitively complex (Stabell, Carlisle) and prefer to assimilate complex rather than simple data. Since particular cognitive styles seem to be associated with particular occupational specialities (Keen), we can often identify which categories of effort will be perceived as expensive by a class of managers.

The list below summarizes some of the above aspects of the phychology of individual differences and also provides some broad estimates of managers' assessment of the marginal costs of effort, based on responses of users of DSS (Keen and Scott Morton, Andreoli and Steadman, Stabell) and of analytic methods in general:

(1) Computation is limited by memory, training and intelligence. Regardless of cognitive style, most managers avoid computation or delegate it to a calculator.

(2) Specification depends on cognitive style. Analytic individuals naturally rely on it, but the majority of empirical studies of decision making suggest that most people find it difficult and even unnatural (Edwards). For example, users of interactive systems that require them to assess probabilities or make simple choices based on trade-offs between two clearly defined alternatives are markedly inconsistent in their judgments (Zaints and Wallenius)

(3) Search does not seem to be constrained by ability, nor are there significant differences among individuals of particular cognitive styles. However, the normative logic of rationality requires a comprehensive search for alternatives. The descriptive reality

of incrementalism (Lindblom) suggests that man is not only a tool-making but search-evading animal. The weighting factor placed on search is obviously very high indeed.

(4) Inference is highly constrained by ability. The regression fallacy, insensitivity to sample size, absurdly conservative updating of probabilities on the basis of new evidence, and incorrect assessment of expected values are obvious and almost universal aspects of human judgment, even among trained experts (Tversky and Kahnemann, Beach, Dawes, Mitroff). Under conditions of incompetence, the marginal cost of effort may seem to be low -- decision makers do not evade inference, but simply do it badly.

(5) Assimilation depends on ability, particularly cognitive complexity. There is some evidence that individuals prefer to assimilate particular types of data. In terms of the Myer-Briggs Type Indicator[10] (Kilman, deWaels, McKenney and Keen), "Sensing" people rely on concrete "hard" information and "Intuitive" ones on conceptual data; "Feelers" validate analysis in terms of emotive responses and "Thinkers" in relation to external logic (Myers).

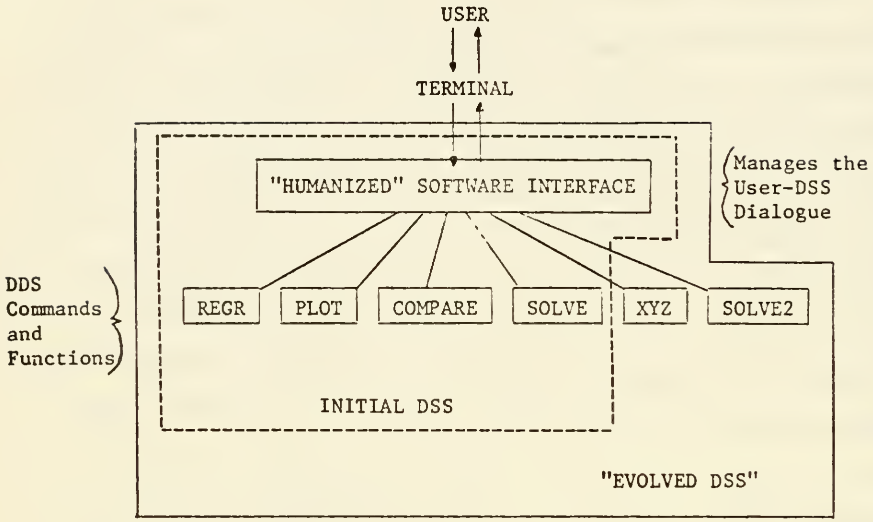
(6) Explanation is situational in terms of the marginal economics of effort. The cost depends on the gap between the individual's own mode of analysis and validation, and the organization's requirements, traditions, norms, etc.

Decision Support Systems

If the above argument is correct, a DSS is a problem-solving aid that either lowers the cost of carrying out an existing mode of analysis or encourages the individual to increase his or her level of reaction from routine to adaptive or adaptive to fundamental. Sometimes the DSS imposes its own costs, such as learning to use the system (a high fixed cost), structuring the problem in relation to the DSS (Specification) and making sense of its output (Assimilation). The "improvement" in the decision process facilitated (though not necessarily caused) by the DSS comes from the movement towards a deeper level of reaction. Gore's simple framework in itself implies a calculus of effort: a "better" solution is likely from heuristic rather than rule-based problem-solving and from analytic method rather than heuristics, but at a cost. Models and information systems in general provide these improved solutions; Decision Support as a philosophy of design and implementation reduces the perceived costs of obtaining them.

The assertions above are central to both a theory of Decision Support and a practical methodology for design of DSS. The argument so far has of necessity been abstract and focuses on decision making. The rest of this paper applies the concepts to building DSS. They can be illustrated in terms of a "typical" DSS (Figure 1), which contains an analytic model such as a linear programming routine (Holloway and Mantey), a simple simulation (Urban, Little) or an information retrieval subsystem (Gerrity). These facilities are accessed through -- and in many ways disguised by -- a software interface that manages the user-machine dialogue.

FIGURE 1 - DSS DESIGN FEATURES


USER
TERMINAL
"HUMANIZED" SOFTWARE INTERFACE
Manages the User-DSS Dialogue
DDS Commands and Functions
REGR
PLOT
COMPARE
SOLVE
XYZ
SOLVE2
INITIAL DSS
"EVOLVED DSS"

Generally, the DSS will be command-driven; the user determines the next step in the analysis through commands such as "PLOT", "REGR" (regression), "COMPARE, or "SOLVE". Clearly, the DSS will support and extend Computation; any decently designed computer system at least relieves the user of the burden of arithmetic calculations and generally routinizes far more complex operations. Here, the marginal effort to the user is essentially zero.

A distinctive aspect of almost all DSS, especially in contrast to many OR/MS models is that they can dramatically reduce the cost of Search. The marginal effort in examining the additional alternative is close to zero. Holloway and Mantey embedded a linear programming routine in a

DSS and found that parents and school administrators found no difficulty in using this analytic methodology; they explored alternatives that they would surely not have considered using heuristic and incremental strategies. They did not, however, randomly generate alternatives but selected them on the basis of issues raised in their joint discussions, points they each wanted to bring out, and areas of disagreement that needed resolution. Similarly, Scott Morton, Carlson, and Sutton's observations of DSS usage suggest that there is no dramatic increase in the number and type of alternatives explored but that the DSS encourages decision makers to look at "interesting" options that previously they filtered out because of the cognitive strain of Search (and Computation).

It is worth noting that the nontechnical users of Holloway and Mantey's DSS treated the linear program as a simulation -- it allowed them to ask "what if?". Scott Morton's results strongly imply that the main value of his DSS was to move decision makers away from incremental search. If the DSS reduces the cost of examining or looking for more alternatives, the user's level of reaction naturally moves from routine to adaptive to fundamental (and his or her level of aspiration is raised, which makes satisficing more difficult). Obviously, however, some DSS do not reduce the cost of search. If the user has to type in many parameters or respond to questions from the DSS that involve Specification and internal Computation, the effort involved in looking for one more alternative remains high and the decision maker finds low-cost heuristics more attractive.

Few, if any, DSS have been built mainly to support Inference. Shortliffe's MYCIN system, which helps physicians diagnose and prescribe drug therapy for certain bacterial infections, does so. Shortliffe refers to MYCIN as a Decision Support System, but it is an experimental Artificial Intelligence project and not a DSS used in an ongoing organizational context. However, MYCIN demonstrates that a DSS can substantially assist inference; this system is an expert diagnostician.

Most writers on DSS stress the need for the user to be in control of the system. Keen and Scott Morton refer to the "primacy of judgment". The decision maker needs to feel that he or she is in charge. It is apparent from observations of DSS usage that there is thus a need for "psychological validation".[11] Users have to decide whether or not to trust the system. Holloway and Mantey's experience with school administrators and parents shows that people can accept a methodology (in this case linear programming) that they do not understand. These nontechnical individuals could relate to the concept of constraints, checked out the methodology by testing scenarios for which they had a good idea of what the result should be and found the DSS itself easy to use. The answers from the Black Box of the linear program were thus phychologically valid.

Unless the potential users of a DSS have some such basis for trust in the validity of the system, they should surely not accept it. Inference is hard to support because few people are at all good at it. The responses from the DSS are likely to be counterintuitive and hence hard to accept and validate. In terms of the marginal economics of effort, systems to support Inference impose both heavy costs of effort ("How do I make sence of this?") and some degree of risk ("How do I know this is right?") A major skill in designing any DSS is thus to provide a basis for psychological validation; this is most easily and often accomplished by permitting the user to check out scenarios, to treat an optimization routine as a simulation, for example.

Assimilation of information may be increased or reduced by a DSS. The "typical" DSS users graphics for output. The justification has mainly been that this communicates more data, faster. A DSS which expands the users' range of search and carries out extremely complicated computations is also likely to generate complex outputs. If these impose cognitive strain, the net effect may be that while the marginal costs of search and computation (and perhaps inference) are all reduced, the additional effort required in assimilation offsets these advantages. Cognitive complexity theory argues that there is an optimum level of output complexity for a given user. Graphics can help maintain that level; simpler and more communicative formats allow far more density and intellectual sophistication of information to be presented while maintaining the same perceived level of complexity.

Informal experiments, together with the conclusions of much research in cognitive psychology (Neisser) suggests that graphical data is responded to a perceptual and instinctual level while numeric data must be processed more consciously; the effort in assimilating graphics is thus very low. (At the same time, the quality of assimilation may also be low -- there is little deliberation and speed of perceptual responses may make the individual vulnerable to simple errors and biases.)

An unanticipated aspect of the evolving use of DSS in organizations has been their value as a communication vehicle (Scott Morton, Gerrity). Gerrity's Portfolio Management System, which was largely intended to help managers in investment decisions, has been heavily employed as a way of explaining current or past decisions to customers. The portfolio manager can give the customer graphs and tables generated from the DSS that communicate quickly and vividly analysis that would be hard to justify verbally. Scott Morton's DSS became a communication and explanation link between marketing and production in a complex planning process. His study indicates that a consequence of this is that managers will explore more options and make more complex plans because they can use the DSS to explain them to each other. In all these cases, the cognitive processes of individual problem-solving have been complemented by support for Explanation. By contrast, Little's Brandaid, a DSS built on the basis of a "decision calculus", a set of design criteria for building tools for managers, has been rejected by some potential users because it did not mesh with the organization's "Explanation" system, the procedures and formats required in presenting plans to senior marketing managers (de Waele, Alter).

On the whole, the emphasis in Decision Support on building the system around the manager's existing process (though aiming to extend and alter that in most cases) and on tailoring it to his or her perspective, vocabulary and concepts has meant that few DSS in use impose large efforts of Specification. This is not true of many interactive models in OR/MS which are technically identical to particular DSS, except in their lack of "human engineering". Dyer's system, designed to help individuals make situational tradeoffs in problems involving multiple criteria (MCDM), requires frequent specifications. Almost all models based on Bayesian decision analysis require the user to estimate probabilities; however simple the format of these estimates, they seem extremely difficult to elicit.[12] Standard optimization techniques similarly require prior specification of objective functions and weights. Perhaps the clearest distinction between OR/MS models and DSS is that the latter accept judgments and leave specification (and often inference) to the manager. It is thus easy for the decision maker to use the DSS for search, computation and explanation without ever being asked to commit more effort to specification.

Dyer's model and similar interactive systems built by Bernayoun, and Zionts and Willenius are explicitly intended to reduce the amount of specification needed to solve optimization problems involving multiple criteria. The software interfaces are very cumbersome, so that the systems are not easy to communicate with. It is worth noting that DSS have mainly been built by individuals skilled in the design of interactive systems and trained in the MIS tradition. They have tended to ignore the value of analytic models for Decision Support. By contrast, the builders of systems for MCDM come out of OR/MS and are relatively insensitive to the need for human engineering and are content with FORTRAN interfaces that are hard to use and that can intimidate and frustrate non-technical users. MCDM models reduce some of the need for specification but DSS can go further because of their emphasis on the user's perspective and on the quality of the user-machine dialogue.[13]

DSS and the Marginal Economics of Effort

Decision Support is a philosophy of the role of computer-based decision aids within the problem-solving process. It begins from observing a decision process and defining what improvement means for specific individuals or classes of individuals in a specific context. A Decision Support System is a means to the end of Decision Support and will be built around whatever technical facilities are available. In practice, this means a combination of information system components, simple models, data base management facilities and interactive software.

The specific facilities contained in the DSS will have some perceived value -- if they do not, the system will of course never be considered. The potential user must weigh this value against the relative costs of effort. The most apparent costs will be the fixed ones of adjusting to and learning the system.

If the benefits of the DSS are large and obvious, the user may well choose to make the investment. In many cases, however, at least some of the benefits must be taken on faith and if the interface is hard to deal with (mistakes are easily made and not forgiven by the DSS which then crashes, or the user has to refer constantly to a thick manual or spend several minutes working out what response is required by the prompt "?"), the fixed cost of the effort will be a major barrier to acceptance.

Many commentators stress the need for humanized interfaces (Sterling, Keen, Little) but at times this seems close to cosmetics, sugaring the pill by making the system friendly, polite, easy to learn, etc. If one views the decision to adopt a DSS as depending mainly on the assessment of its benefits, then much of the emphasis on human engineering is hard to justify. If, however, the marginal economics of effort are viewed as the key determinant of the choice then such tailoring of the software interface to the user becomes essential, not cosmetic. A command-driven system, with "help" routines, plausibility checks, choice of "expert" or "novice" modes and high-quality display devices reduces the fixed cost of learning. They also reduce the semi-fixed set up costs incurred at the start of each run (structuring the problem, remembering which commands are needed).

The incremental costs of effort implicit in a DSS can generally be reduced by skillful design. Accomplishing this invariably means incurring software overhead. For example, a "Help" command, which prompts the user whenever "?" is typed, in no way adds to the problem-solving facilities of the system and requires a large amount or program code which takes time to write and may waste storage. However, it makes the system easier to learn. Clearly, the closer the implicit problem-solving style of the DSS is to the user's existing habits, concepts and procedures, the lower the effort of adjustment, especially in relation to Assimilation, Search and Specification.

The following list summarizes how design of the system can reduce the economics of effort for each category of cognitive cost; it is obviously incomplete and any list partly depends on an assessment of the specific situation and users.

(1) Computation should always be reduced by the DSS, provided the computation can be requested quickly and easily. For example, "COMPUTE NPV AT 10% FOR FLOWS -20K, 5x 10K, 45K" imposes minimal effort. By contrast, the following sequence is sufficiently complicated to discourage the user from asking for more than essential calculations:

```
CALL NPV
DISCOUNT RATE?  .10  ("10" is treated by the DSS as 1000%)
NUMBER OF CASH FLOWS?  6
FIRST CASH FLOW START OF YEAR 1 (0) OR END (1)?  1
CASH FLOW (1)?  -20000
          (2)?   10000
          (3)?   10000
          (4)?   10000
```

(5)? 10000

(6)? 45000

The more effort required, especially in relation to the payoff from that effort, the more cost effective it may be for the decision maker to reduce his or her level of reaction. Here, for example, it is likely the user of the system will retreat towards incremental analysis and limit calculations to a main case and variations.

(2) Search costs can obviously be reduced by the provision of commands that reduce set up and perform a range of operations quickly. The extreme is "SIMULATE" which calculates the impact of a specific set of decisions and parameters (such as GNP, interest rates or demand estimates). If users can also change values easily (e.g. "ALTER 5,3 TO 35M" -- "alter variable 5, year 3 to 35 million" -- or "INCREASE ALL COSTS BY 12.5%), they will find that searching widely for and fine-tuning alternatives imposes no cost. The designer needs to ask how much incremental effort is needed for the user to input the data for one more alternative. If the effort is large, then search will be expanded only if the benefits are substantial. Morton's research implies that where the benefits are small but real and the incremental cost of search is low, users become far more systematic in their evaluation.

(3) The effort involved in Inference can be dramatically reduced but only if the user trusts the answer. Here is a situation where a

DSS -- or indeed any analytic model -- can provide large payoffs. The problem is how to lower the cost and risk. To a large extent, the quality of the other facilities in the system help establish the worth of those supporting Inference. That said, since Inference is easy in terms of effort, but generally weak in terms of performance by the unaided human decision maker, this seems to be one area where the benefit side of the equation must be stressed rather than the effort side. At the same time, the rule holds true that for a given level of benefit, the cost can and should be reduced by careful design of the user-system dialogue:

1) how easy is it for the user to specify parameters?
2) how close is the dialogue to the user's own thought processes?
3) how easy is the output to comprehend ?
4) how can the output -- the inference -- be assessed and validated?

Once again, Holloway and Mantey's case study provides useful conclusions. The user need not understand the inferential methodology but must trust it. (Comparatively few users of standard statistical packages really understand the details of the method, let alone how they are translated into a computer routine; they accept it because it has consensual trust.)

(4) It seems likely that many DSS increase the costs of Assimilation and that this explains disuse after an initial trial period. Certainly, several DSS provide too much information, not so much

in terms of content as of elaboration of detail and format. DeWaele's study of user attitudes towards "decision calculus" DSS similar to Little's Brandaid indicates that many marketing managers find the strain of making sense of the outputs too much; they can grasp the results intellectually but have to make an unnecessary investment to do so.

DSS designers have relied on serendipity in using graphics whenever possible. There has been little systematic study of output choices and effects. The hypothesis that emerges from the propositions presented here concerning the economics of effort is that graphics substantially eases the cost of assimilation at the potential risk of loss of conscious attention to data. In addition, it seems likely that:

a) graphical outputs are responded to at a perceptual rather than congnitive level;

b) the lower the user's level of reaction to the problem situation (and hence the lower the investment in effort he or she is willing to make) the more graphics will be preferred over tabular reports (and as a corollary, the more fundamental the problem is seen, the more tabular data will be preferred).

(5) From the experience gained from using DSS on a continued basis in organizations, the more apparent it becomes that such systems immensely ease the efforts required in Explanation. Morton's and Gerrity's DSS evolved increasingly in this direction and more recent systems which have not been so fully documented

confirm this trend. Obviously, this assertion is true only if the software system and the output formats are well-designed and communicative. One implication of this is that a DSS can be effective as a device for organizational and joint problem-solving may be facilitated simply by having at a key organizational node -- such as the planning decision involving marketing and production described by Morton -- a vehicle that permits sharing of ideas, analysis and explanation of logic. Morton found that conflict between groups was substantially reduced by each party being able to say "Well, let's look at that option" or "Let me show you why that won't work". (Here again, if the marginal cost of examining another alternative is close to zero, there is every incentive to listen to someone's line of reasoning and not reject it a priori.)

The Impact of Decision Support Systems on Individual Problem-Solving

It is extremely difficult to evaluate the impact of a DSS since it is unlikely to lead to dramatically better decision outcomes, measurements are lacking to track improved effectiveness, and no true experimental design is generally possible in an organizational setting because other situational factors cannot be controlled for. The line of argument presented here does not contradict that of other commentators -- a DSS does indeed lead to consideration of more alternatives and that is a likely indicator of improved decision making. What is provided here is a conceptual explanation of the impact of such a personalized tool on problem-solving processes that are hard to evaluate and measure. If we combine the insights gained from research on bounded rationality, which emphasizes the impact of computer-based support on cognitive ability, with the concept of managers perceptions of the economics of effort, we can extend the lessons gained from studies of specific DSS and derive some testable propositions that can help extend Decision Support from a pragmatic approach to building DSS towards a formal concept of man-machine problem-solving.

The key proposition is that a DSS exploits the benefits to be obtained from analytic methodologies and information technology by improving the marginal economics of effort. The implication of this is that technical design of any DSS must focus on identifying and responding to manager's assessments of and weights placed on particular categories of effort (it makes no sense, for example, to reduce the cost of Search and simultaneously increase the effort required for Assimilation).

The second proposition is that managers' "purchase" of a DSS is based on the economics of effort rather than the payoffs of analytic techniques (cf. Stabell). This argument has some subtle implications. Rather than look for more powerful and effective models and methods, Decision Support should build on existing techniques and find ways in which their cognitive costs can be reduced. This flies in the face of much of the normative strategy of OR/MS which generally tries to persuade managers to make the necessary investment to gain the benefits of rational analysis.

Decision Support will often choose to work well within the technical state-of-the-art and "package" standardized models. For example, an LP can be disquised as a simulation; to the user, the "system" is the software interface that manages the user-machine dialogue.[14] From the perspective of OR/MS, this is a trivial application and a misuse of the designer's skills -- the user should be trained or persuaded to adopt the logic of optimization. Decision Support takes the value of linear programming as a given and then tries to reduce the perceived costs of using it. One may easily take any LP code and identify the various costs of effort -- search, assimilation, explanation, etc. The design choice is how and by how much to reduce them. The resulting interactive system will contain many "cosmetic" features. These are cosmetic only to the analyst. To the user, they will often lower the costs of effort to a point where they are less than the perceived benefits. At that stage, the user will purchase the system.

The simple definition of improved decision making that emerges from this line of argument is that a DSS encourages the user to move to a deeper level of reaction. The concept of bounded rationality and the normative logic of rationality imply that deeper level of reaction leads to better decision outcomes, simply because the degree of effective cognitive investment is larger and the depth and range of analysis broader. Again, the design choice for a DSS is how to simulate this movement. We can assume that a manager will commit the necessary resources for a given level of reaction; if the DSS reduces the cost of those resources, we can expect a spontaneous shift of attention and an effective increase in level of reaction.

One important implication of these propositions is to establish Decision Support as more than just a simplistic packaging of information systems and models. The software interface, which is the feature distinguishing a DSS from other interactive packages, interactive models and on-line data retrieval and management systems, becomes the main focus of attention for the designer. Building a DSS requires, above all, skills in designing humanized interfaces and a secondary ability to exploit any self-contained technique or product developed within the MIS or OR/MS fields. The main criteria for design, for both selection of routines and definition of the interface are:

a) the user's perceptions of and ability in committing additional effort to search, inference, assimilation, etc.;

b) the likely improvement in level of reaction prompted by lowering these costs of effort;

c) the net balance between incremental effort and benefits implied by the DSS.

The final point to be made here is that OR/MS has so entirely neglected the economics of effort that its products are adopted relatively infrequently and it has had little direct impact on management decision making in complex and ambiguous problem situations. Decision Support provides a conceptual and practical basis for exploiting the immense potential of OR/MS by complementing the model-builder's conceptual skills with those of humanized design, while extending the computer specialists' largely atheoretical abilities by providing a richer intellectual base. The end is Decision Support, the vehicle a mixture of MIS and OR/MS techniques, and the opportunities unlimited.

NOTES:

1. See Keen and Scott Morton for a definition of Decision Support Systems, chapter 1, pp. 1-12.

2. See Keen and Hackathorn, who distinguish Personal Support Systems (PSS) from Organizational Support Systems (OSS). Microcomputers also permit a "portable" technology, which frees the user from many organizational, political, financial and technical constraints. See Keen, Information Access Systems for Policy Analysts.

3. See, especially, Simon and Taylor.

4. This term is Simon's. It is interesting to note that though it is central to most managerial research on decision making, it has still not appeared in Webster's dictionary.

5. Simon, Sciences of the Artificial, p. 38.

6. Ackoff and Sarieni, p. 443.

7. See Hirschman and Lindblom, p. 211.

8. Tversky and Kahnemann provides an excellent summary.

9. Mintzberg's field study of how executives spend their time has had substantial influence on behavioral work on management decision making. His book brings to mind the adage "managers are people who act before they think -- if they ever do think -- and analysts think before they act -- if they ever do act."

10. The Myer-Briggs Indicator, though based on Jungian type theory, has been adopted by a number of researchers interested in cognitive style as a reliable, meaningful and convincing measurement device. The MBII uses four scales to classify individuals in terms of mode of perceiving and of using information.

11. See Keen, Interactive Computer Systems for Top Managers, and Holloway and Mantey.

12. See Keen, The Evolving Concept of Optimality, and Zelany (Ed.).

13. See Zelany (Ed.) and Starr and Zelany (Ed.), for presentation of MCDM techniques and Keen and Scott Morton, chapter 6, for a discussion of DSS design principles.

14. Keen, Interactive Computer Systems for Top Managers.

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